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STA RESEARCH ON
SUPERCONDUCTING MATERIALS

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SCIENCE & TECHNOLOGY JAPAN

STA RESEARCH ON SUPERCONDUCTING MATERIALS

906C0016 Tokyo CHODENDO ZAIRYO KENKYU MARUCHIKOA PUROJEKUTO in Japanese
22 May 88 pp 1-24

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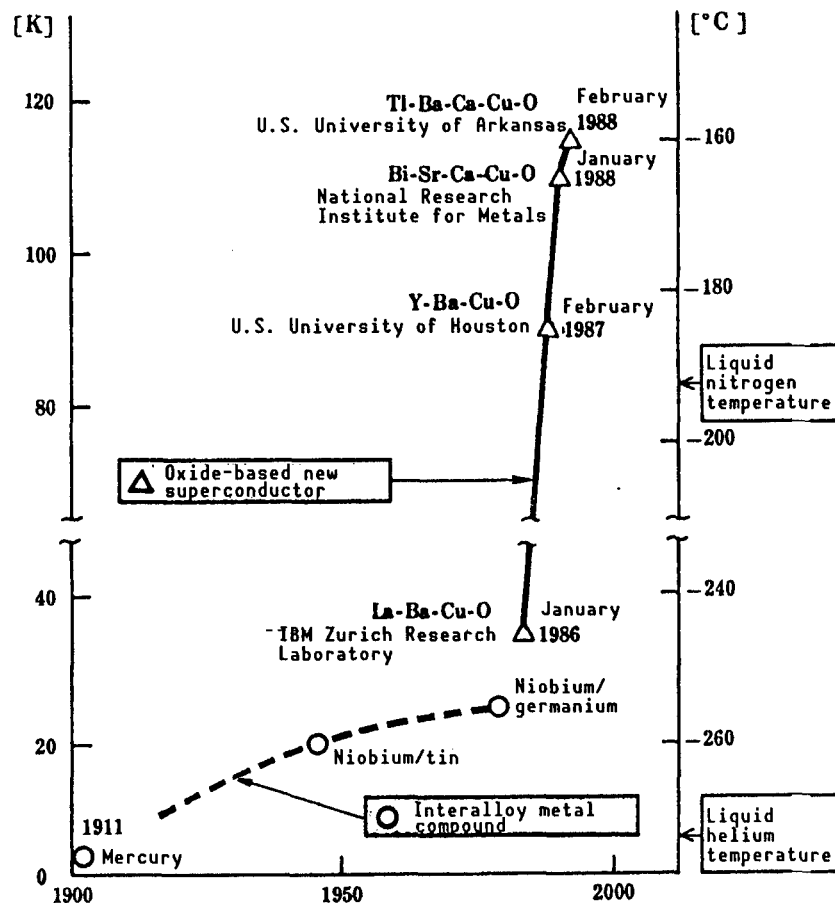
STA Multicore Research Project on Superconducting Materials

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[Text] Superconducting Material Research Multicore Project

Oxide-based new superconductors discovered in 1986 currently possess a critical temperature (T_c) of more than 100 K, which is higher than the temperature of liquid nitrogen—77 K. This has been made possible by the discovery of new bismuth-based and thallium-based materials. Such new superconductors, therefore, appear to bring about the technological innovations in the 21st century and expectations for the application are growing. The research and development of such new superconductors, however, has just begun and there are many problems to be resolved. The Science and Technology Agency, therefore, has founded the "Superconducting Material Research Multicore Project" to contribute to international R&D as well as to finally attain the practical use of new superconductors. At the same time we must be fully aware of the current state of the technology.

To promote basic multilateral infrastructure research on new superconducting materials, it is necessary to be flexible in promoting joint research, in which researchers take the leadership, which is open to both domestic and overseas R&D institutes, and the exchange of researchers and information (hereinafter referred to as "joint research, etc."). The core of this research will be the R&D potentials of the national test and research institutes, special corporations, etc. For such a purpose, the "Superconducting Material Research Multicore Project" has been established. A November 1987 report on the "Meeting on Superconductors" held by the Scientific Technology Policy Committee points out that it is necessary to promote basic infrastructure research, utilize existing research development potentials, etc.



Historical Change in Superconductor Critical Temperature (T_c)

Outline of Multicore Project

1. Basic Idea

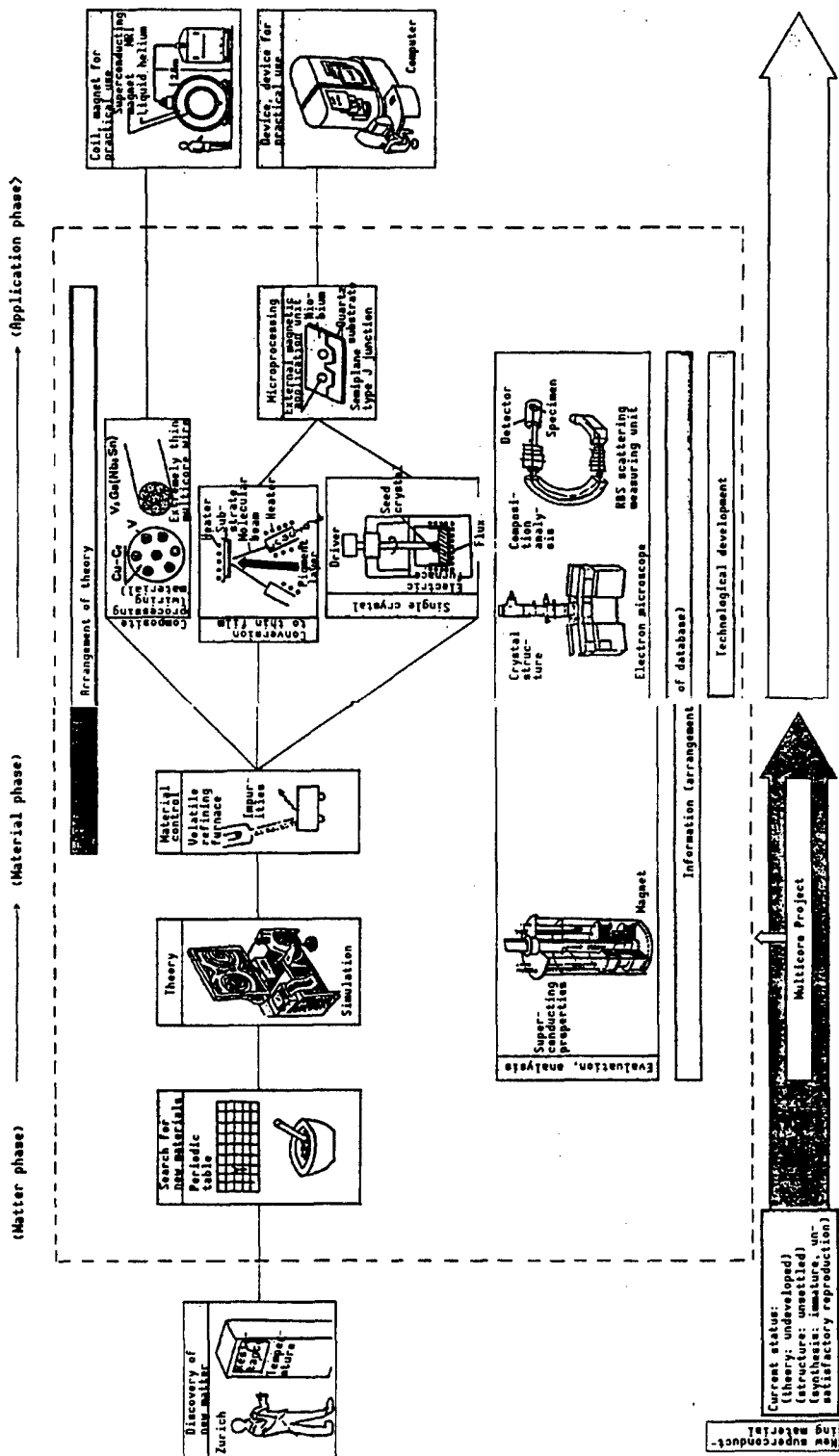
The following items play vital roles

♦ Basic Infrastructure Research

- Executing multilateral basic infrastructure research on matter and materials to achieve the practical use of new superconductors.

♦ Invisible Research Activities Utilizing Existing Potentials

- Complete utilization of research potentials already accumulated in both hardware and software to promote basic infrastructure research.
- Promotion of integrated R&D based on an organic linkage between each research institute.



♦ Research System Opened to Both Domestic and Overseas R&D Institutes

- Enhancing one's own research potentials, mainly by using advanced infrastructure research facilities and promoting joint research, etc., under a system open to both domestic and overseas R&D institutes.

♦ Research System With Emphasis on Researchers

- Enhancing researchers' originality to promote basic infrastructure research.
- Establishing a flexible research system with emphasis on the subjectivity of researchers.

2. Purpose of the Project

The purpose of the multicore project is to develop practical application of new superconductors with properties (critical temperature, etc.) superior to those of conventional superconductors, including oxide-based superconductors. The project covers such basic infrastructure research as "theory and data-bases," "synthesis/structural control," "analysis/evaluation," and "technical development."

3. Project Organization and Operation

The project will be executed under the following organizational and operational system, based on the basic idea.

♦ Research Core

- To attain the multicore project targets, a "research core" will be located at institutes with existing research potentials. Research cores will promote joint research. Institutes with a research core will be referred to as a "core institute."

- At present, established research cores are listed in the separate table. Depending on the state of R&D of new superconducting materials in both domestic and overseas R&D institutes, however, the necessity of the research cores concerned will be reviewed.

- Researchers at each core institute and those (other than core institutes) who cooperate in research comprise "core researchers" for each research core. A "research core member" who represents each research core will handle coordination and other tasks necessary for the execution of research activity for each research core.

♦ Multicore Project Committee To Promote Superconducting Material Research

- For the smooth execution of the multicore project, the "Multicore Project Committee To Promote Superconducting Material" will be formed. The committee will be comprised of representatives from each core institute, knowledgeable

people from industry, universities, and government institutes. The committee will not only receive status reports on the progress of research but will also study basic matters concerning the implementation of the multicore project such as research plans and research systems.

- The head of each core institute will cooperate in the smooth execution of the multicore project, while giving due consideration to the results of studies done by the committee.

♦ Core Leader Communications Meeting

The promotion committee will hold "core leader communications meetings" to ensure close communications between each research core and study matters necessary to promote the multicore project. The meeting will be attended by research core leaders and knowledgeable people as necessary. It is an organization in which researchers will take the lead in substantially promoting the multicore project.

♦ Promotion of Joint Research

- Each research core will arrange advanced infrastructure research facilities necessary to promote joint research between each research core, and between each research core and research institutes other than core institutes.

- Each research core will promote joint research in response to requests made by research institutes other than a core institute for joint research, with consideration given to each institute's own potentials.

- Research core leaders will establish "working groups" as necessary to promote joint research, etc. The working group for the most part will consist of core researchers; researchers and other personnel from institutes other than core institutes that are involved in joint research will be made members of the working group as necessary.

- Joint research, etc., will be carried out in accordance with regulations and systems governing the current joint research of each research institute. To facilitate smooth execution of joint research, requirements of various systems will be reviewed.

- Cooperation will be obtained from the Society of Nontraditional Technology and the New Superconducting Material Forum to hold international symposiums and workshops, exchange information between domestic and overseas researchers and research institutes, and publicize research results, technological surveys, etc. Thus, a close link with associated research institutes will be maintained.

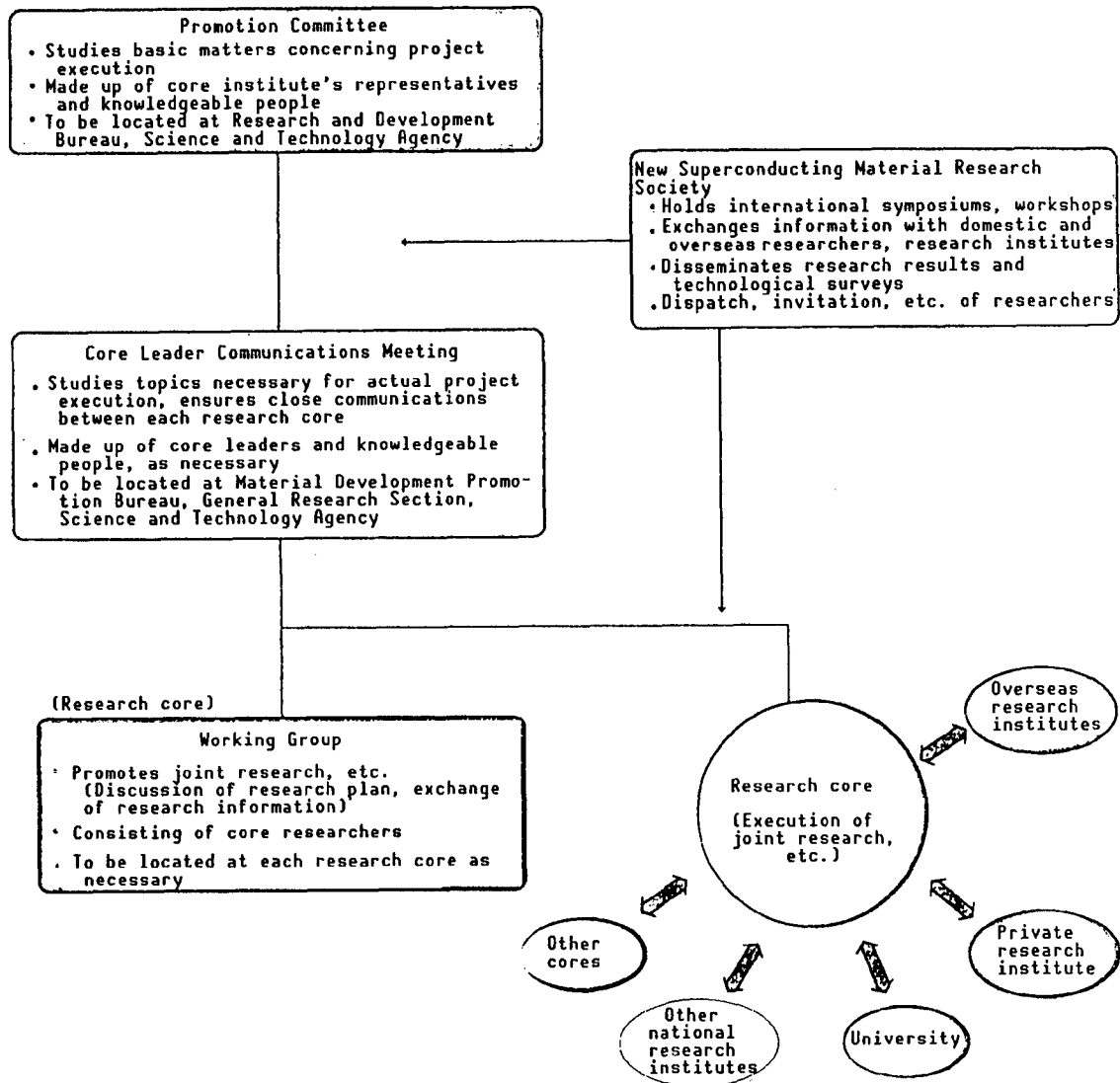
♦ Research Core

Domain	Research core	Core institute
Theory Database	Theory Database	National Research Institute for Metals National Research Institute for Metals
Synthesis/ Structural control	New matter search Raw material control Thin-film attainment Single-crystal attainment Microprocessing Composite processing Space environment utilization	National Institute for Research in Inorganic Materials National Research Institute for Metals National Research Institute for Metals National Institute for Research in Inorganic Materials Institute of Physical and Chemical Research National Research Institute for Metals National Space Development Agency of Japan
Analysis, Evaluation	Evaluation of superconductor performance Crystal-structure analysis Highly sensitive composition analysis Irradiation/analysis Measurement/analysis support	National Research Institute for Metals National Institute for Research in Inorganic Materials Institute of Physical and Chemical Research Japan Atomic Energy Research Institute Foundation for Promoting Material Science Technology
Techno- logical develop- ment	Technological development	New Technology Development Corp.

As of May 1988

4. Project Promotion Mechanism

The multicore project execution mechanism can be illustrated as follows.



♦ Participation as Research Core

• National test and research laboratories, special corporations, public service corporations, and others, can participate in the multicore project as a research core through studies done by the multicore project promotion committee, which are based on the state of domestic/overseas R&D of new superconducting materials and also on the existing R&D potentials of the research institutes concerned.

(As of May 1988)

Members of the "Multicore Project Committee To Promote Superconducting Material Research"

(Chairman)	Shinroku Saito	Professor Emeritus, Tokyo University of Engineering
Toshio Ito	Manager	Central Research Laboratory, Mitsubishi Electric Corp.
Hiroshi Iwasaki	Manager	Optical Electronics Research Institute, NTT
Toichi Okada	Professor	Industrial Science Research Laboratory, Osaka University
Koichi Kitazawa	Professor	Engineering, University of Tokyo
Ken Sugiura	Manager	Electronics Technology Center Research Laboratory
Yasutsugu Takeda	Manager	Central Research Laboratory, Hitachi, Ltd.
Kyoji Tachikawa	Professor	Engineering, Tokai University
Shoji Tanaka	Professor	Department of Science, Tokai University
Kenichi Tsukamoto	Manager	Communication General Research Laboratory
Atsushi Nagai	Manager	Toshiba General Research Laboratory
Aiko Hara	Deputy manager	R&D Division, Sumitomo Electric Industries, Ltd.
Harumi Hirabayashi	Professor	High Energy Physics Research Laboratory
Yoshio Muto	Professor	Metal Material Research Laboratory, Tohoku University
Masaru Goto	Director	New Material Development Corp.
Toshio Sada	Director	Institute of Physical and Chemical Research
Sadaru Sawai	Director	Power Reactor and Nuclear Fuel Development Corp.
Nobuo Sedaka	Manager	National Institute for Research in Inorganic Materials
Ryuichi Nakagawa	Manager	National Research Institute for Metals
Toyojiro Kouda	Director	Japan Atomic Energy Research Institute
Akio Horiuchi	Director	Japan Science and Technology Information Center
Takashi Mayama	Director	Marine Science and Technology Center
Shunpei Yamazaki	Managing director	Foundation for Promoting Material Science Technology
Yoshio Yorimizu	Director	National Space Development Agency of Japan

♦ Participation as Core Researcher

- It is possible to become a staff member of a core institute, and thereby participate in the multicore project as a core researcher, by participating in the outside-researcher receiving system (e.g., simultaneous appointment systems and guest researcher systems) provided by the concerned core institute.

- It is also possible to appoint overseas researchers as public service personnel, under the Research Exchange Promotion Law.

♦ Execution of Joint Research With Research Core

- Each research core will conduct joint research based on the systems provided by the core institute. Consideration will be given to the research potentials of the involved research core and the research institute making the request for joint research.
- Joint research, etc., with overseas research institutes will be conducted in the same manner as the above. Joint research, etc., between government institutes will be carried out in accordance with international agreements.

Outline of Each Research Core

1. Theory Core (National Research Institute for Metals)

♦ Outline of Research

Of basic research projects on superconducting materials, clarification of the superconducting phenomenon, in particular, plays a vital role in improving superconducting characteristics, as well as in studying new superconducting matter.

In this core, research will emphasize two themes.

- Detailed analysis of electronic structure to search for the unique qualities of new superconducting matters;
- Construction of theoretical models for superconducting mechanism and identification of superconducting characteristics based on such models.

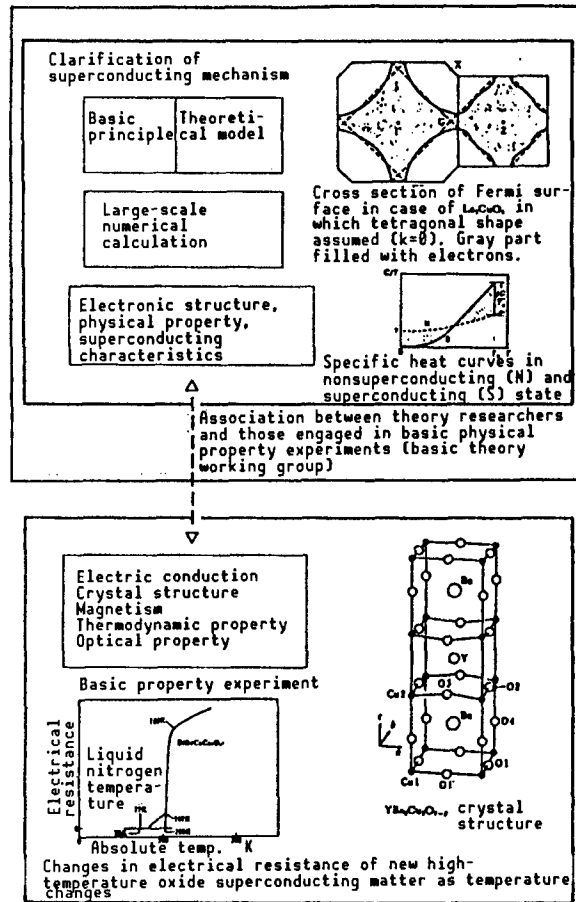
Large-scale numerical calculations using high-speed, large-sized computers and basic physical property experiments to verify the effectiveness of theories play vital roles in this research.

♦ Method of Operation

In this core, joint research will be conducted with the cooperation of pure theory researchers, numerical analysis researchers, basic physical property researchers, etc. It is necessary to promote the exchange of researchers engaged in the clarification of the superconducting mechanism. To this end, research meetings (basic theory working group) will be held regularly so that theory researchers and researchers involved in basic physical property experiments can meet and introduce, discuss, and study the latest research results. It is also planned that international workshops be held to study the superconducting mechanism.

♦ Major Equipment/Technology

- Simulation processing equipment



Theory Core

♦ Major Research Results

- Analyzed the electronic structure of La- and Y-group copper oxide high-temperature superconducting matter, particularly the peculiarities of the electronic structure caused by the omission of oxygen and changes in the oxygen position.

♦ Research System

Core leader	Manager of Basic Physical Property Research Department, National Research Institute for Metals	Meisei Yoshikawa
Unit leader	Researcher, Research Group No 1, Basic Physical Property Research Department, National Research Institute for Metals	Tamio Oguchi
Research cooperator	Professor, Metal Material Research Laboratory, Tohoku University; Professor, Physical Property Research Laboratory, University of Tokyo	Masashi Tachiki Kiyoyuki Terakura

2. Database Core (National Research Institute for Metals and Others)

♦ Outline of Research

Based on database research in the metal group superconducting materials, physical property/characteristics data, including new superconducting matter, will be converted to a database with the cooperation of the New Superconducting Material Research Society, institutes participating in the multicore project, and others. In other words, experts in individual fields concerning characteristic values to be stored in the database will study data indication modes, etc. Along with this, nucleus data obtained by the separate measurements of common specimens will be arranged. Also, studies will be done on database utilization technology to search for new materials. Further, with the cooperation of the New Superconducting Materials Forum, technological surveys will be carried out in regard to the practical application of new materials.

♦ Method of Operation

To carry out the projects entrusted to it, the New Superconducting Materials Forum will establish a study group. Then, research will be allotted to researchers participating in the study group, and the results will be made available to members of the forum through workshops and other means.

♦ Major Equipment/Technology

- Alloy design workstation.
- Data utilization system terminal workstation.

♦ Major Research Results

- Preparation of a trial database on laminated film and metal-group superconducting materials.

◆ Research System

Core leader		Manager, Damage Mechanism Research Dept., National Research Institute for Metals [NRIM] (03-719-2271)	Bin Nishijima
Unit 1	Leader	Chief researcher, Surface/Interface Control Research [NRIM]	Yuuji Asada
	Contents of research	Study of basic physical property field database, etc.	
Unit 2	Leader	Leader, Subgroup No 1, Research Group No 1, NRIM	Yoshiaki Tanaka
	Contents of research	Study of database in material technology	
Unit 3	Leader	Manager, Research Office No 1, Material Design Research Dept., NRIM	Kenichi Hoshimoto
	Contents of research	Investigation, etc., of trends in superconducting research in each application field	
Unit 4	Leader	Manager, Space Experiment Program Office, Planning Control Dept., National Space Development Agency of Japan	Shuuji Ozawa
	Contents of research	Investigation of trends in future technology such as application to space systems	
Unit 5	Leader	Manager, Solid Physics Research Office No 1, Japan Atomic Energy Research Institute	Yukio Kazumata
	Contents of research	Investigation of trends in application to energy technologies such as nuclear fusion	
Unit 6	Leader	Deputy chief researcher, Frontier Research Group, Tokai Works, Power Reactor and Nuclear Fuel Development Corp.	Ryouji Asou
	Contents of research	Investigation of trends in application to energy technologies such as new type reactor cycle, etc.	

3. New Matter Search Core (National Institute for Research in Inorganic Materials)

♦ Outline of Research

Based on research concerning the synthesis of diamond film, various rare-earth-oxide group new matter, and oxide-group new superconducting matter, the core will seek matter with superior superconducting characteristics and new structures.

♦ Method of Operation

• Success in the search for new matter depends greatly on the ingenuity and originality of the researchers. The new matter search core, therefore, will be operated with due regard for researchers' independence. Many aspects of research will be connected to those of other cores. Joint research, therefore, will be carried out while contact is maintained with other cores at all times.

♦ Major Equipment Technology

Atmospheric search

Solid phase reaction process

- Dry process
- Multistep wet process
- Sol-gel process

Liquid phase reaction process

- Melted material ultra-quenching process

Vapor phase reaction process

- Surface reforming process

High-pressure search

Solid pressurization process

- High-pressure solid phase reaction process
- Multistage pressurization high-pressure synthesizing process
- Sealing pressurization process

Gas pressurization process

- High-pressure gas pressurization process
- 30,000-ton high-pressure press
- Ultra-quenching thick film synthesizing equipment
- High/low-temperature X-ray diffractometer
- Secondary ion mass spectrometer (SIMS)
- SQUID magnetization rate measuring equipment

♦ Major Research Results

- Identification of Y-Ba-Cu-O group superconductors.
- Identification of Bi-Ca-Sr-Cu-O group superconductors.

♦ Research System

Core leader		General researcher of Research Group No 5, National Institute for Researchers in Inorganic Materials [NIRIM] (0298-51-3351)	Bin Okai
Unit 1	Leader	Chief researcher, Research Group No 5, NIRIM	Yasutoshi Hasegawa
	Contents of research	Search for new materials by solid phase synthesis under atmospheric pressure	
Unit 2	Leader	Chief researcher, Research Group No 5, NIRIM	Kazushi Hirota
	Contents of research	Search for new matter using high pressure and high oxygen pressure	
Unit 3	Leader	Chief researcher, Research Group No 5, NIRIM	Kouichiro Takahashi
	Contents of research	Search for new matter by vapor/liquid phase synthesis	
Research cooperator		Professor, Physical Science, Tsukuba University	Koutaro Sakumichi

4. Raw Material Control Core (National Research Institute for Metals)

♦ Outline of Research

The method of controlling raw materials plays a vital role in improving the performance of superconducting materials. On the basis of research on chemical-reaction control technology, superfine manufacturing technology, high-pressure control technology, etc., this core manufactures highly pure raw materials and controls the composition and shape of raw powders, thus developing highly efficient superconducting materials. It carries out joint research with the private sector and universities in the field of selection, kneading, burning, etc., of raw materials and intends to enlarge areas of joint research in the future.

♦ Method of Operation

Raw material core subcommittee meetings will be held several times a year in the form of joint research with Unit 3 to establish research policy, allocate research work, discuss research results, and facilitate research feedback.

♦ Major Equipment/Technology

- Solid-phase electrolytic equipment.
- Optical-beam crystal-growing equipment.
- Optical excitation reaction equipment.

♦ Major Research Results

- Refining of rare-earth element liquid phase.
- Refining 4A group/5A group element volatile decomposition.
- Optical excitation refining of Mo, W, etc.

♦ Research System

Core leader		Manager, Reaction Control Research Dept., National Research Institute for Metals (03-719-2271)	Shiro Yoshimatsu
Unit 1	Leader	Manager, Research Office No 2, Reaction Control Research Dept., NRIM	Ryousuke Hasegawa
	Contents of research	Manufacture of high-purity raw materials	
Unit 2	Leader	Leader, Subgroup No 3, Research Group No 3, NRIM	Yosiya Kaieda
	Contents of research	Development of highly dense superconductors by HIP and CIP	
Unit 3	Leader	Leader, Subgroup No 2, Research Group No 4, NRIM	Masaya Ozawa
	Contents of research	Structure/shape control by the composite superfine manufacturing technology	

5. Thin Film Core (National Research Institute for Metals)

♦ Outline of Research

The development of technology for synthesizing superconducting thin films (at low temperatures) that can be used at the temperature of liquid nitrogen or higher will greatly affect future research in electronics. The quick response of Josephson devices have raised great expectations that they can be used as future high-speed operation devices. Great expectations are also placed on superconducting wiring as a key technological breakthrough against the so-called "thermal" wall involved in large-scale integration.

To attain application to the above electronics field, it is indispensable to freely synthesize superior submicron superconducting thin films. The synthesis of thin films at low temperatures is another important research target. Individual components and elements of oxide high-temperature superconductors differ in the physical/chemical properties from each other. This core, therefore, will establish the technology for synthesizing superconducting thin films at low temperatures while properly utilizing the features of individual components and elements, as well as the atom/molecule level structural control technology.

♦ Method of Operation

The superconducting characteristics of oxide high-temperature superconductors are extremely sensitive to their component ratio. This core, therefore, will fabricate, on an experimental basis, thin film synthesizing equipment to be used exclusively for oxide high-temperature superconductors by optimizing the evaporation source and utilizing in-situ evaluation equipment, etc., under a joint research system consisting of industries, universities, and government institutes.

♦ Major Equipment/Technology

- Equipment for synthesizing multiple-element, low-temperature compounds.
- Equipment for preparing structural control laminated film.
- Auger electron spectrochemical analyzing equipment.
- Equipment for measuring the Mossbauer effect.

♦ Major Research Results

- Studied the relation between the omission of oxygen and superconducting characteristics in the Y-Ba-Cu-O group.
- Studied the effect of adding fluoride and successfully manufactured superconducting films that are not dependent on substrate.

- Analyzed heat treatment temperatures and the relation between composition and high-temperature phase formation in Bi-Cu-Sr-O.

♦ Research System

Core leader		Manager, Surface/Interface Control Research Dept., NRIM (0298-51-6311)	Keiichi Ogawa
Unit	Leader	Manager, No 2 Research Office, Surface/Interface Control Research Dept., NRIM	Keikichi Nakamura
	Contents of research	Low-temperature synthesis of oxide superconducting thin film	
Research cooperator		Professor, Central Research Laboratory, Kyoto University	Naomasa Bando

6. Single-Crystal Core (National Institute for Research in Inorganic Materials)

♦ Outline of Research

On the basis of the experience in the research of the growth of various oxide single crystals for use in magnetic resonance devices, lasers, nonlinear optics, etc., this core intends to grow large, high-quality single crystals of high temperature superconducting matter and to offer them for various measurements.

Clarification of the superconducting mechanism requires not only the development of theories but also demonstrations based on physical measurements using good quality single crystals. The use of single crystals is also indispensable to determine a precise crystal structure and to analyze the bonding state. In some cases, the use of centimeter-sized crystals is required.

This core will conduct flux search, phase balance measurement, R&D of various crystal growth technologies, including evaluation of the growth of single crystals, as a series of procedures. In addition, the crystal growing mechanism will be analyzed using the in-situ technique. Further, research on the initial process of plate-shaped crystal growth arising from epitaxy (an important phenomenon for practical application) will be conducted using the process to complete plated crystal.

♦ Method of Operation

For research, close exchange of information and joint research will be carried out as necessary with the researchers of universities, national and other public research laboratories, and the private sector.

♦ Major Equipment/Technology

Crystal synthesis: Pickup unit, condensing floating zone process unit
Top seed method equipment
Crystal observation: High-temperature-stage microscope
Picture processing unit

♦ Major Research Results

- Determination of liquid phase surface of the $\text{YBa}_2\text{Cu}_3\text{O}_x$ phase and synthesis of single crystals of such a phase through annealing.
- Synthesis of Bi-Sr-Ca-Cu-O superconductor-phase single crystals using the FZ process.

♦ Research System

Core leader		General researcher, Research Group No 13, National Institute for Research in Inorganic Materials (0298-51-3351)	Shigeyuki Kimura
Unit 1	Leader	Chief researcher, Research Group No 6, NIRIM	Shunji Takegawa
	Contents of research	Growing of single crystals, etc.	
Cooperating researchers		Professor, Metal Material Research Laboratory, Tohoku University Professor, Physical Property Research Laboratory, University of Tokyo	Satoshi Komatsu Fumihiko Takesue

7. Microprocessing Core (Institute of Physical and Chemical Research)

On the basis of experience in establishing lithography technology used to manufacture multilayer devices using niobium having a high reactivity, this core will try to apply microprocessing technology to manufacture high-temperature superconducting thin films and to create superconducting devices, such as high-temperature superconductor Josephson devices.

This core carries out the following items of work.

- (1) Three-dimensional devices with short coherence length of high-temperature superconductors controlling the length of the weak bonding portion.

(2) Leveling surfaces to secure superconducting contact between high-temperature superconducting thin films having a three-dimensional structure, removing surface insulating layer, and establishing a low-temperature manufacturing process.

(3) Using nonaqueous processes to secure watertightness to apply the lithography process of microprocessing.

♦ Method of Operation

Utilizing potentials in the development of subsurface-type Josephson devices and thin film manufacturing technology (using laser) for new devices, this core carries out basic research, including joint research, to convert new superconductors to devices.

♦ Major Equipment/Technology

- Simultaneous evaporation multitarget spatter equipment.
- Laser evaporation equipment.
- Light decomposing CVD equipment.
- Laser surface reforming equipment.
- Molecular beam epitaxial equipment.
- Electron beam exposure equipment.
- Dry etching equipment.
- Lithography equipment.

♦ Results of Research

- Developed niobium multilayer Josephson device lithography preparing process technology (developed millimeter-wave detecting device, switching device, seven-channel SQUID, etc.).
- High-temperature superconductor laser sputtering evaporation.
- Studied the LSI manufacturing dry process.
- Studied laser CVD.

♦ Research System

Core leader		Researcher, Microwave Physical Research Office, Institute of Physical and Chemical Research (RIKEN) (0484-62-1111, ext. 3214)	Hiroshi Outa
Unit 1	Leader	Researcher, Microwave Physical Research Office, RIKEN	Hiroshi Outa
	Contents of research	Development of new high-temperature superconducting thin film and application to Josephson junction	
Unit 2	Leader	Chief researcher, Semiconductor Engineering Research Office, RIKEN	Kouichi Toyoda
	Contents of research	Preparation of new superconducting thin film by laser processing	
Unit 3	Leader	Deputy chief researcher, Laser Science Research Group, RIKEN	Katsunobu Aoyagi
	Contents of research	Application of highly efficient high-temperature superconductor thin film to new superconductor electronics	

8. Composite Processing Core (National Research Institute for Metals)

♦ Outline of Research

Japan took the initiative in developing basic technology on V-Ga and Nb-Sn wiring materials. On the basis of such experience, this core will develop various wiring material manufacturing technologies, etc., using the vapor-phase reaction process, liquid-phase reaction process, solid-phase reaction process, etc., for new superconducting matter and will put such technologies into practical use.

♦ Method of Operation

This core will not only develop various manufacturing processes with emphasis on joint research but also study the possibility of practical applications of such processes by conducting characteristic tests.

♦ Major Equipment/Technology

Vapor-phase reaction process

- Sputter process
- Vacuum evaporation process
- CVD process

Liquid-phase reaction process

- Electron beam irradiation process
- Melt quenching process

Solid-phase reaction process

- Powder compound material process

Chemical reaction process

- Sol-gel process
- Application process

Other processes

- Plasma spray coating process, etc.

♦ Stabilization/Conversion to Conductor

Evaporation of good conductor matter, plating, improvement of strength, etc.

♦ Major Research Results

- Developed surface diffusion process (V_3Ga superconducting tape manufacturing technology).
- Developed composite processing technique (V_3Ga extremely thin multicore wire manufacturing technology).
- Converted oxide superconducting compounds ($LaBaCuO$, $YBaCuO$) to wiring materials.

◆ Research System

Core leader		General researcher, Research Group No 1, National Research Institute for Metals (0298-51-6311)	Hiroshi Maeda
Unit 1	Leader	Leader, Subgroup No 1, Research Group No 1, National Research Institute for Metals	Yoshiaki Tanaka
	Contents of research	Conversion to wiring materials, etc., by the vapor reaction process, etc.	
Unit 2	Leader	Leader, Subgroup No 2, Research Group No 1, National Research Institute for Metals	Kazumasa Togano
	Contents of research	Conversion to wiring materials, etc., by the solid/liquid phase reaction process, etc.	
Unit 3	Leader	Leader, Subgroup No 4, Research Group No 1, National Research Institute for Metals	Masashi Wada
	Contents of research	Conversion to wiring materials, etc., by the chemical reaction process, etc.	
Unit 4	Leader	General researcher, Research Group No 1, National Research Institute for Metals	Hiroshi Maeda
	Contents of research	Conversion to wiring materials, etc., using special technologies	

9. Space Environment Utilization Core (National Space Development Agency of Japan)

◆ Outline of Research

As special features of space environment, microgravity ($10^{-6}G$), high vacuum (10^{-6} torr), extensive solar energy, and other areas can be cited. Particularly, continuous microgravity environment cannot be easily obtained on the ground. In space, therefore, it is highly possible that materials are improved and new materials are created, using phenomena such as nonconvection, nonsettlement, and nonstatic pressures.

The National Space Development Agency of Japan (NSDA) is studying testing opportunities, testing equipment, and testing technology, using aircraft, rockets, NASA space shuttles, and space stations to use microgravity to test materials. The following items can be cited as examples of experiments in which the microgravity environment helps promote the creation of new oxide superconducting matter.

(1) Liquid phase sintering—Even if a part of the sinter has turned into a liquid, no settlement occurs. This makes it possible to manufacture materials by liquid-phase sintering in a uniformly dispersed state.

(2) Vapor-phase synthesis process—This process eliminates the effect of convection and should improve completeness in crystals.

(3) Crystal growth from melt—Crystal growth can be expected solely by diffusion and there is the possibility that good-quality bulk single crystals can be obtained.

◆ Method of Operation

The space environment utilization core intends to disseminate information on space test opportunities, space test themes, and test equipment/technology, and to conduct joint research on these items.

◆ Research System

Core leader		General development staff member, Space Experiment Group, National Space Development Agency (NSDA) (03-769-8190)	Tadaaki Mochida
Unit	Leader	Chief development staff member, Space Experiment Group, NSDA	Seiji Higuchi
	Contents of research	Study of space experiment opportunities, space experiment themes, and experiment equipment and technology	

10. Superconductor Performance Evaluation Core (National Research Institute for Metals)

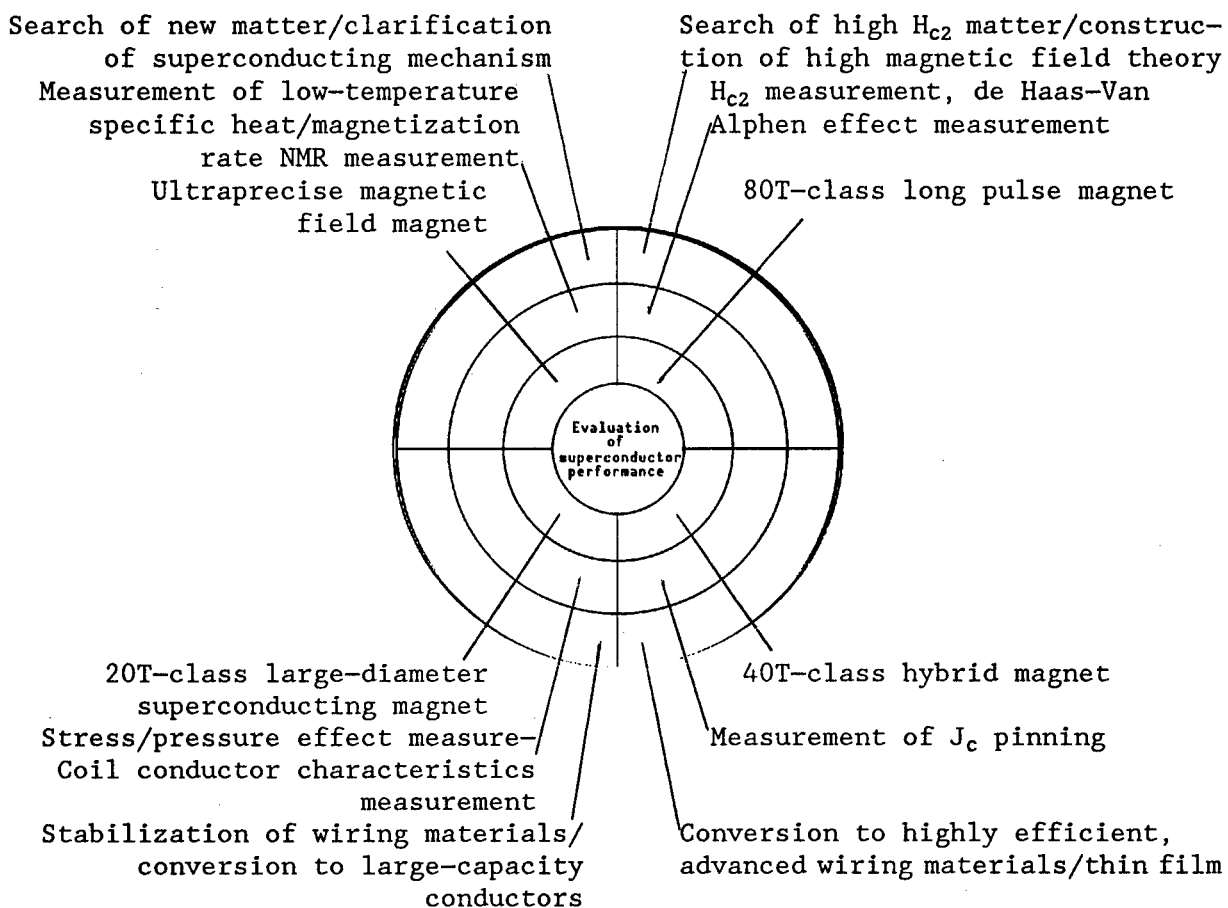
◆ Outline of Research

Superconductors have close connections with magnetic fields. Both basic and application research on superconducting materials, therefore, require the use of strong magnetic fields. Japan developed superconducting magnets, etc., with magnetic flux density of 17.5 tesla earlier than other countries. On the basis of such experience, this core will develop and arrange strong magnetic field magnets, ultraprecise magnetic field magnets, etc., and to evaluate the performance of superconducting materials from various standpoints.

◆ Method of Operation

Joint research will be carried out on the following topics using various magnetic fields.

- (1) Verification of superconducting mechanism of new superconducting matter.
- (2) Evaluation of new superconducting materials.
- (3) Evaluation of characteristics of new superconducting materials in the magnetic field.
- (4) Study of new superconducting material manufacturing processes and optimization of manufacturing conditions.
- (5) Synthesis of new superconducting materials in the magnetic field.



♦ Major Equipment/Technology

- 80T-class long-pulse magnet.
- 40T-class hybrid magnet.
- 20T-class large-diameter superconducting magnet.
- Equipment measuring magnetic characteristics in an ultraprecise magnetic field.

♦ Major Research Experience

The following technology, etc., have been developed so far:

- Magnet technology using various high magnetic field superconducting wiring materials (V_3Ga surface diffusion tape, V_3Ga extremely thin multicore wires, $(Nb, Ti)_3Sn$ extremely thin multicore wires).
- Superconducting magnet using extremely thin multicore compound wiring materials for the first time in the world.
- Superconducting magnet generating a magnetic flux density of 17.5T, which at the time was the strongest in the world.
- Superconducting magnet generating a magnetic flux density of 18.1T, which at the time was the strongest in the world.

♦ Research System

Core leader		General researcher, Research Group No 1, National Research Institute for Metals (0298-51-6311)	Hiroshi Maeda
Unit 1	Leader	Leader, Subgroup No 3, Research Group No 1, NRIM	Yasushi Inoue
	Contents of research	H_{c2} measurement, etc., using 80T-class pulse magnet	
Unit 2	Leader	Leader, Subgroup No 3, Research Group No 1, NRIM	Yasushi Inoue
	Contents of research	I_c measurement, etc., using 40T-class hybrid magnet	
Unit 3	Leader	Leader, Subgroup No 4, Research Group No 1, NRIM	Masashi Wada
	Contents of research	Measurement of stress effects using 20T-class large-diameter magnet, etc.	
Unit 4	Leader	Manager, Research Office No 1, Basic Physical Property Research Dept., NRIM	Haruyoshi Aoki
	Contents of research	NMR measurement, etc., using ultraprecise magnetic field magnet	
Unit 5	Leader	Leader, Subgroup No 1, Research Group No 1, NRIM	Akayoshi Tanaka
	Contents of research	Development, etc., of cryogenic refrigerating/cooling technology	

11. Crystal Structure Analysis Core (National Institute for Research in Inorganic Materials)

♦ Outline of Research

On the basis of experience in the matter/material research using the world's most advanced technology for crystal structure analysis, this core develops and installs new types of high-resolution electron microscopes. It will thereby observe and analyze the local structure of superconducting matter, etc. This core also analyzes a crystal mean structure and observes phase transition by X-ray diffraction and neutron diffraction. Further, this core analyzes electron structure, intergranular structure by the highly accurate energy analyzing process. Thus, this core intends to help clarify the superconducting theory and convert superconductors to materials.

♦ Method of Operation

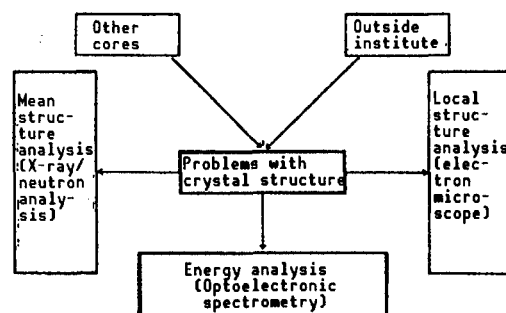
Other cores such as the new material search core, or outside research institutes may run into problems with crystal structure analysis. Upon their request, this core will tackle such problems in the form of joint research. Where other cores or outside research institutes desire to learn the ways and means of analyzing crystal structures, this core will receive their researchers or allow them to use test equipment, etc.

♦ Major Equipment/Technology

- Electron microscope (1 Å) with an ultrahigh resolution.
- Powder X-ray diffractometer.
- Optoelectronic spectrometer (ESCA).
- Program analyzing crystal structure using a (least-squares) process.
- High-resolution electron microscope image analyzing program.
- Optoelectronic spectrum analyzing program.

♦ Major Research Results

- $\text{YBa}_2\text{Cu}_3\text{O}_y$ superconductor crystal structure analysis using the X-ray/neutron beam (least-squares) process.
- Bi-Sr-Cu-O superconductor crystal structure analysis using high-resolution electron microscopes.
- Superconductor electron structure analysis using the optoelectronic spectrometer.



♦ Research System

Core leader		General researcher, Research Group No 4, National Institute for Research in Inorganic Materials (0298-51-3351)	Shigeo Horiuchi
Unit 1	Leader	Chief researcher, Research Group No 13, NIRIM	Yoshio Matsui
	Contents of research	Local microstructure analysis using electron microscopes	
Unit 2	Leader	Chief researcher, Research Group No 15, NIRIM	Fujio Okamura
	Contents of research	Mean crystal structure analysis by X-ray/neutron diffraction	
Unit 3	Leader	Chief researcher, Research Group No 10, NIRIM	Junzo Tanaka
	Contents of research	Electron structure, grain boundary analysis by optoelectronic spectrum process, etc.	
Research cooperator		Assistant professor, Material Engineering, Tsukuba University	Shigeo Sueno

12. Highly Sensitive Composition Analysis Core (Institute of Physical and Chemical Research)

♦ Outline of Research

This core analyzes the composition, etc., of good-quality, high-temperature superconductor specimens (prepared under various conditions) with high sensitivity and high accuracy, thereby clarifying the effect of a change in the composition on the high-temperature superconductor structure, electronic state, magnetism, etc. Thus, this core intends to clarify the superconducting mechanism of high-temperature superconductors and to design superior superconductors.

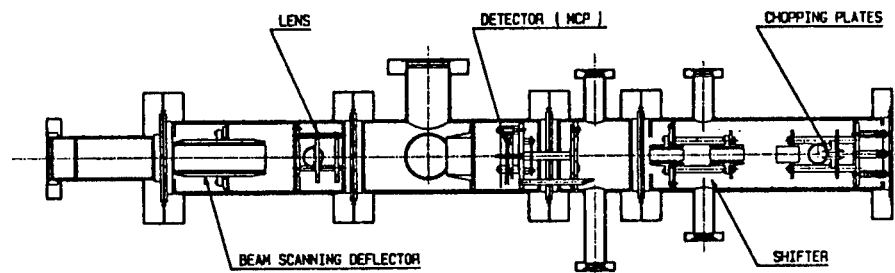
♦ Method of Operation

On the basis of special characterization technologies such as those used to measure various ion properties, etc., this core carries out the following analysis including joint research, using the Rutherford backscattering spectrometry (converted to microbeams), low-speed ion scattering spectrometry, secondary ion mass spectrometers, X-ray optoelectronic spectrometry, analytic electron microscopes, scanning tunnel microscopes, etc.

- (1) Highly sensitive and accurate analysis of average composition of the total specimen.
- (2) Analysis of composition distribution in depth from a specimen's surface to core or from individual crystal grain boundaries to core.
- (3) Optional local composition analysis to study the inequality of specimens or the phase of several matters.
- (4) Positional analysis in crystal lattices, such as additive dissimilar elements and oxygen omission.

♦ Major Equipment/Technology

- Rutherford backscattering spectrometry (RBS).
- Direct collision ion scattering spectrometry.
- Scanning tunnel microscope technology.
- Muon spectrometry technology.



Direct Collision Ion Scattering
Spectrometer (CAICISS) Structure

♦ Major Research Results

The following equipment and technologies were developed.

- Direct-collision, slow ion scattering spectrometers and surface analyzing technology.

- Technology for analyzing surface using a scanning tunnel microscope.
- Physical property analyzing technology using various ion scattering processes.

♦ Research System

Core leader		Chief researcher, Friction Engineering Research Office, Institute of Physical and Chemical Research (0484-62-1111, ext. 3121)	Masakazu Aono
Unit 1	Leader	Friction Engineering Research Office, RIKEN	Masakazu Aono
	Contents of research	Composition analysis and structural analysis using the ion scattering process	
Unit 2	Leader	Chief researcher, Metal Physics Research Office, RIKEN	Kanetada Nagamine
	Contents of research	Research on the correlation between composition/structure and micromagnetism	
Unit 3	Leader	Chief researcher, Magnetism Research Office, RIKEN	Kouichi Katsumata
	Contents of research	Research on the correlation between composition/structure and spin order state	

13. Irradiation/Analysis Core (Japan Atomic Energy Research Institute)

♦ Outline of Research

Japan Atomic Energy Research Institute (JAERI) so far has analyzed the structure of matter and done research on irradiation damage by constructing and operating large-sized equipment for use in research such as nuclear reactors and tandem accelerators. On the basis of such research, this core will analyze the crystal structure of oxide superconducting matter, study irradiation damage, using large-sized irradiation equipment (reactors, accelerators, etc.), neutron diffraction equipment, etc.

♦ Method of Operation

This core will establish a committee of experts from inside and outside JAERI and hold meetings to help implement core work. In the meetings, the core members will report, evaluate, and study the status of research in JAERI, and discuss research programs.

♦ Major Equipment/Technology

- γ -ray irradiation equipment:

 - ^{60}Co source.

- Electron beam irradiation equipment:

 - Cockcroft-Walton accelerator
 - Linear accelerator

- Neutron irradiation equipment:

 - Reactor

- Ion irradiation equipment:

 - Tandem accelerator
 - 2 MV Van de Graaff accelerator

- Neutron spectroscope:

 - Measurement of crystal structure
 - Lattice vibration
 - Magnetic structure, etc.

- Others:

 - Development of acceleration cavity
 - Synthesis of actinoid specimens
 - Development of superconducting magnets for nuclear fusion

♦ Major Research Results

- Developed and manufactured an acceleration cavity using Nb.

- Developed large-sized superconducting magnets for nuclear fusion.

- Studied solid irradiation damage.

- Studied crystal structure, lattice vibration, and magnetic structure using neutron diffraction.

♦ Research System

Core leader		Manager, Physics Department, JAERI (0292-82-5894)	Naoki Shikazono
Unit 1	Leader	Manager, Material R&D Office, Fuel/Material Engineering Dept., JAERI	Kiyoshi Watanabe
	Contents of research	Creation of raw materials for use in experiments	
Unit 2	Leader	Manager, Solid Physics Research Office No 3, Physics Dept., JAERI	Tatsu Funabashi
	Contents of research	Structural analysis by neutron diffraction, etc.	
Unit 3	Leader	Chief researcher, Physics Dept., JAERI	Hiroshi Naramoto
	Contents of research	Research of irradiation damage	
Unit 4	Leader	Deputy chief researcher, Physics Dept., JAERI	Eisuke Minehara
	Contents of research	Development of acceleration cavity, measurement of high-frequency characteristics	
Unit 5	Leader	Manager, Superconducting Magnet Research Office, Nuclear Fusion Research Dept., JAERI	Susumu Shimaki
	Contents of research	Development of nuclear-related superconducting equipment	

14. Measurement/Analysis Support Core (Material Science Technology Promotion Corp.)

♦ Outline of Research

Using the following processes and equipment, this core evaluates materials, focusing on the solid surface and local and microanalysis.

♦ Method of Operation

• X-Ray Photoelectron Spectroscopy (XPS/ESCA)

This process makes possible the qualitative, quantitative, and chemical state of solid surfaces as well as microscopic ESCA.

In the case of oxide superconductors, it is possible to analyze the behavior of oxygen, the chemical state of composing atoms on solid surfaces, and interfaces between superconductor phases and nonsuperconductor phases.

- **X-Ray Diffraction Process (XRD)**

This process can identify the matter of solid and thin film specimens, analyze their crystal structure, and measure their grain size.

It is possible to analyze the crystal structure of oxide superconductors by precisely measuring lattice constants and crystal grain size.

- **Secondary Ion Mass Spectrometer (SIMS/IMA)**

This equipment can measure impurity distribution by identifying an extremely small amount of impurities and analyzing concentration and two-dimensional depth direction.

The use of new types of electric guns (vertical incident) has made it possible to carry out a complete self-compensation of charge-up, thus having served to improve the ability of analyzing insulated specimen impurities with high sensitivity.

- **Superconducting Quantum Interference Device (SQUID)**

With respect to oxide superconductors, various magnetic properties are measured at a wide range of temperatures (1.8 to 400 K) and at maximum external magnetic fields (+5.5~5.5T) with a high resolution (maximum 10^{-8} emu). Very high sensitivity can also be obtained. The SQUID, therefore, can detect weak changes in magnetization rate.

- **Scanning Type Auger Electron Spectroscopy (μ -AES/SAM)**

This process makes it possible to carry out the qualitative, quantitative, and local analysis of solid surfaces with high sensitivity, as well as to measure element maps.

- **Other Processes**

Fourier transform infrared spectroscopy (FT-IR), scanning electron microscope (SEM), energy dispersion type X-ray analysis process (EDX).

◆ Research System

Core leader		Manager, Material Evaluation Division, Material Science Technology Promotion Corp. (03-482-2522)	Masahiro Kudo
Unit	Leader	Chief, Material Evaluation Division, Material Science Technology Promotion Corp.	Senori Takegoshi
	Contents of research	Measurement and analysis using various types of equipment	

Technological Development Core (New Technology Development Corp.)

Utilizing the functions of the New Technology Development Corp., this core intends to improve the results obtained through multicore project by putting them into practical use.

◆ Method of Operation

• Collection and Evaluation of Research Results

This core collects and evaluates the results of completed multicore projects as well as the results of research conducted by universities, national research institutes, etc. It also studies ways to apply such results to the various systems of the New Technology Development Corp., depending on the progress and contents of the research.

• Improvement of Basic Research Results--High Technology Consortium System

To search for a variety of possible practical applications of research results (basic patents), the corporation forms a technical development promotion consortium by having several firms from diverse industries participate, which will promote a variety of tests. In this case, the corporation provides less than half of the expenses to the firms performing important duties (testing period: 1 year).

• Development of Research Results

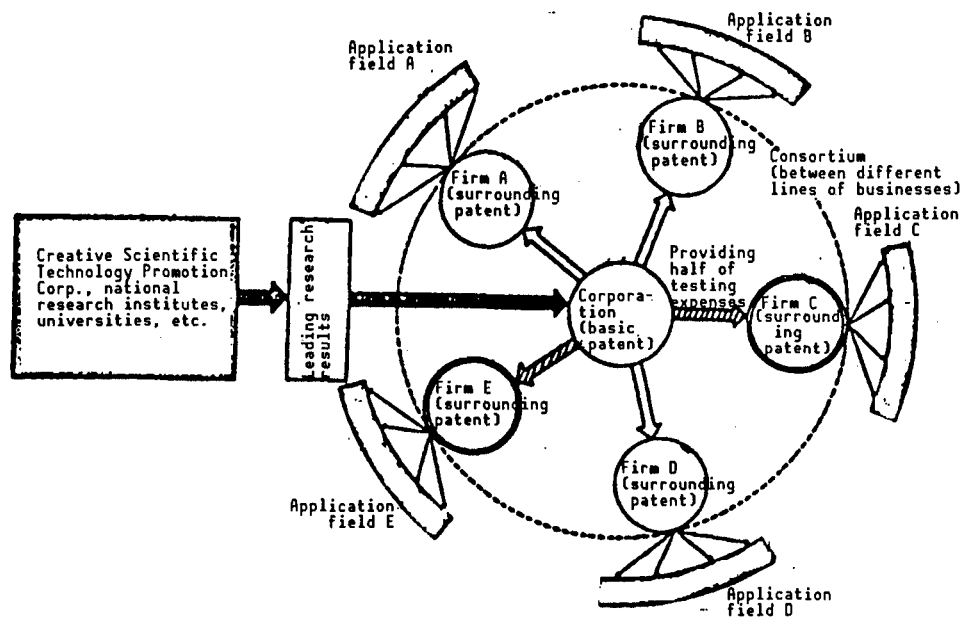
(1) Entrusting Development System

There are some research results that involve large technological risks in developing practical application. In such cases, the corporation leaves the development work to the firms concerned but furnishes necessary funds. Where the firms have succeeded in developing practical applications, they must reimburse the development funds to the corporation in installments over a period of 5 years without paying interest. These firms are required to pay a

royalty to the corporation based on their sales. Firms that have not developed practical applications are not required to reimburse development funds.

(2) Development Introducing System

When the research results do not involve large technological risks in the process of developing practical application, the corporation introduces such results to firms that desire to use such crystal lattice. In addition, the corporation promotes the practical application of research results by publicizing them in technical information magazines and other means.



High-Technology Consortium System

♦ Major Research Results

High-technology consortium system

- Ultraparticulates gas deposition
- Perovskite ceramic materials

Entrusting development system

- Superconducting magnet lead wire (alloy system, intermetal compound system) manufacturing technology
- Highly pure diamond sinter manufacturing technology

Development introducing system

- Metal short fiber manufacturing technology
- Magnetic fluid production process

◆ Research System

Core leader		Manager, Project Dept., New Technology Development Corp. (03-507-3031)	Mikio Murota
Unit 1	Leader	Manager, Project No 1 Section, Project Dept., New Technology Development Corp.	Kazuo Oumi
	Contents of research	Collection/evaluation of research results	
Unit 2	Leader	Manager, Patent/Technological Development Section, Technological Development Dept., New Technology Development Corp.	Noboru Fujikawa
	Contents of research	Operation of a high-temperature consortium	

(References)

(As of May 1988)

Science and Technology Agency	Manager, Material Development Promotion Office, R&D Bureau 2-2-1 Kasumigaseki Chiyoda-ku, Tokyo 100	Mikio Hattori 03-581-5271
National Research Institute for Metals	Planning manager 2-3-12 Nakameguro, Meguro-ku, Tokyo 153	Ryo Kimura 03-712-5773
National Institute for Research in Inorganic Materials	Planning manager 1-1 Namiki Sakura-mura Niiharu-gun Ibaraki 305	Akitoshi Higuchi 0298-51-3363
Japan Atomic Energy Research Institute	Director, Investigation, Planning Office 2-2-2 Uchisaiwa-cho Chiyoda-ku, Tokyo 100	Masahiro Nishidou 03-592-2107
Japan Scientific Technology Information Center	Director, Investigation, Planning Office 2-5-2 Nagata-cho, Chiyoda-ku, Tokyo 100	Natsuo Onodera 03-581-5809
Institute of Physical and Chemical Research	Assistant manager, Planning Office 2-1 Hirosawa, Wako-shi, Saitama 351	Utao Yamazaki 0484-62-1551

[continued]

[Continuation of table]

New Technology Development Corp.	Manager, Patent and Technological Development 2-5-2 Nagata-cho, Chiyoda-ku, Tokyo 100	Noboru Fujikawa 03-507-3057
Power Reactor and Nuclear Fuel Development Corp.	Chief, Planning Dept. 1-9-13 Akasaka Minato-ku, Tokyo 107	Minoru Sakuma 03-586-3708
National Space Development Agency of Japan	Manager, Space Test Program Office, Planning/Control Dept.	Shuuji Ozawa 03-435-6166
Marine Scientific Technology Center	Manager, Planning 2-15 Natsushima-cho, Yokosuka-shi, Kanagawa 237	Tsutomu Kubota 0468-66-3811
Foundation for Promoting Material Science Technology	Manager, Planning 3-11-1 Kamisohigaya, Setagaya-ku, Tokyo 157	Katsuo Ota 03-482-2522
New Superconducting Material Research Society	Managing director, Unexplored Scientific Technology Association Toranomon Kotohira Kaikan Building, 1-2-8 Toranomon, Minato-ku, Tokyo 105	Tsunehisa Kurino 03-503-4681

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